BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D.C. 20024

B70 06042

SUBJECT: Description and Status of the Design of the Particles and Fields Subsatellite - Case 320

DATE: June 15, 1970

FROM: A. G. Weygand

ABSTRACT

The status of the design of the Particles and Fields (P&F) Subsatellite was discussed at a technical management review meeting held at the TRW, Incorporated location in Redondo Beach, California on May 14 and 15, 1970. The objectives of this meeting were equivalent to those of a preliminary design review (PDR) and included a review of the preliminary design of the P&F Subsatellite by TRW and a review of the technical portion of the preliminary draft of the End Item Specification for the Particles and Fields Subsatellite which was dated May 4, 1970. A brief description of the physical configuration and the operating modes of the P&F Subsatellite and a summary of the subsatellite attitude stabilization analyses performed by TRW are presented. In addition, a brief description of the preliminary design of the particle and field experiments and the mechanical and electrical power subsystems and a detailed description of the preliminary design of the communications subsystem of the P&F Subsatellite are presented. The action items generated during this meeting and their disposition are also reviewed.

(NASA-CR-110710) DESCRIPTION AND STATUS OF THE DESIGN OF THE PARTICLES AND FIELDS SUBSATELLITE (Bellcomm, Inc.) 30 p

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

The status of the design of the Particles and Fields (P&F) Subsatellite was discussed at a technical management review meeting held at the TRW, Incorporated location in Redondo Beach, California on May 14 and 15, 1970. Although this meeting was essentially equivalent to a preliminary design review (PDR), the meeting could not be so named because the contract between MSC and TRW had not been signed before this meeting was convened. However, before conclusion of the meeting on May 15, it was announced that the contract had been signed. Mr. J. H. Johnson, MSC/EE17, NASA Experiment Manager for the P&F Subsatellite, stated that the objectives of this technical management review meeting were to settle upon the design approach for the P&F Subsatellite and to finalize the technical portion of the preliminary draft of the End Item Specification for the Particles and Fields Subsatellite System dated May 4, 1970.

A briefing was given by cognizant TRW subsystem engineers during the morning of May 14 to all meeting attendees. The briefing included a review of the currently proposed design of the various subsystems of the P&F Subsatellite including the mechanical, scientific instruments, electrical power, and communications subsystems and a review of the results of preliminary analyses of subsatellite dynamics, passive thermal design, magnetic cleanliness design, and reliability. A copy of the visual aids used during this briefing can be made available to the interested readers by the writer. At the conclusion of the briefing, the meeting attendees were split into four separated splinter groups; namely, the (a) Mechanical, (b) Scientific Instruments, (c) Electronics, and (d) Program Plans splinter groups. The writer participated in the Electronics splinter group meeting which was assigned the responsibility to review those sections of the technical portion of the End Item Specification for the P&F Subsatellite which were concerned with the electrical power and communications subsystems. The splinter groups regrouped on the afternoon of May 15 at which time the action items generated in the four splinter group meetings were discussed by all meeting attendees and disposition of the action items was made by Mr. Johnson of MSC. Those portions of the technical management review meeting attended by the writer (the briefing, the Electronics splinter group meeting, and the action item review and disposition meeting) will be summarized in the following paragraphs.

A few introductory remarks were made by Messrs. Johnson of MSC and T. Pederson, TRW Program Manager for the P&F Sub-Satellite, prior to the formal briefing. In order to be ready for a July 30, 1971 scheduled launch date, the P&F Subsatellite must be delivered to the Kennedy Space Center (KSC) by May 7, 1971. Since TRW requires five months for subsystem integration and checkout of the P&F Subsatellite, all subsystem hardware must be available by November 30, 1970 except the scientific instruments which are currently scheduled for delivery to TRW from the respective subcontractors (the particles experiments - Analog Technology Corporation and the magnetometer - Time Zero) on December 15, 1970. At this time, portions of the communications subsystem and the scientific instruments appear to be the pacing items. Monthly management reviews will be held at TRW for the subsatellite and at the respective experiment subcontractor locations for the scientific instruments. A PDR for the ground support equipment (GSE) required for support of the P&F Subsatellite during prelaunch activities at KSC will be held at KSC in mid-June. The critical design review (CDR) for the P&F Subsatellite is currently scheduled for mid-July.

2.0 BRIEFING

The portions of the briefing that the writer judged to be important and/or of general interest are summarized in this section except for that portion covering the communications subsystem. Since this subject was covered in greater detail in discussions during the Electronics splinter group meeting, the preliminary communications subsystem design will be described in the next section.

The P&F Subsatellite and its launch platform weighing a maximum total of 95 pounds will be mounted on a deployment mechanism provided as part of the Scientific Instrument Module installed in Sector I of the Service Module (SM) of an Apollo Command and Service Module (CSM). North American Rockwell, Inc. (NR), the SIM integrating contractor, will supply the deployment mechanism while TRW will supply the launch platform and the subsatellite. The launch platform when activated will impart to the subsatellite via a spring operated mechanism a linear velocity of approximately four feet per second and a spin rate of nominally 12 revolutions per minute (rpm) about its longitudinal axis. The subsatellite will be a hexagonal prism with a diameter of 14 inches and length of 30 inches and include three 60 inch booms mounted 120 degrees apart at one end of the prism and an S-band antenna mounted at the other end of the prism on its longitudinal or spin axis. On the face of each of the six sides of the prism will be a solar panel. Cutouts will be provided in two of these six panels to provide viewing ports for the charged particle detectors of the particles experiments. The primary power source for subsatellite operation will be this solar cell array of six panels while a rechargeable 10 ampere-hour silver-cadmium battery will provide the necessary power for subsatellite operation during periods of solar eclipse or when the load requires more power than is available from the solar array alone. The battery will be provided with protection against overcharge as well as excessive discharge. The subsatellite will be designed to use only passive thermal control and to be essentially magnetically clean.

The subsatellite payload will include four charged particle detectors covering a range of particle energies, two solid state telescopes, a biaxial fluxgate magnetometer, and an S-band transponder required to perform experiments S173 (Lunar Particle Shadows and Boundary Layer Experiment), S174 (Magnetometer Experiment), and S164 (S-Band Transponder Data Analysis Experiment). The magnetometer will be mounted on the end of one of the three 60 inch booms. The field of view of the two solid state telescopes will be parallel with the spin axis of the subsatellite while the field of view of the four particle detectors will be perpendicular to the spin axis. It should be noted that the S-band transponder will also be used to provide the communications (command and telemetry) link between the subsatellite and stations of the Manned Space Flight Network (MSFN). The visual aids used during the briefing on the scientific experiments are attached to this memorandum (Attachment 1).

At some time after insertion of the CSM into a 60 nautical mile circular lunar orbit, the subsatellite will be launched into lunar orbit by its spring actuated separation mechanism upon command by a crewman in the Command Module (CM). The subsatellite will be launched with its longitudinal or spin axis approximately perpendicular to the ecliptic plane and will be spin stabilized at 12 rpm. The three booms will be deployed simultaneously as soon as the subsatellite separates from the launch platform. The subsatellite will enable magnetic field, charged particle, and Doppler tracking data to be obtained in lunar orbit for nominally one year. The particles and fields experiments may be conducted during each lunar orbit except for one orbit per day when Doppler tracking data will be obtained and for one orbit per day when the on-board battery will be charged. A block diagram of the P&F Subsatellite is shown in Attachment 2.

Redundant switches will be provided in the subsatellite which disconnect all subsystems from the battery as long as the subsatellite is in the SIM. Immediately upon separation from the CSM into lunar orbit, the switches (either one or both) will operate and connect the battery to the appropriate subsystem of the subsatellite automatically and the S-band receiver will be activated enabling commands sent from the Mission Control Center (MCC) in Houston through a station of the MSFN to be received and executed by the subsatellite. There will be essentially six modes of operation of the P&F Subsatellite which will be selectable by ground command; namely,

(a) Real-time - subsatellite subsystems and experiment data are sampled and transmitted at 128 bits per second (bps).

(b) Data Storage Normal - experiment data is sampled and stored on-board the subsatellite at 8 bps for a maximum of 6144 seconds.

(c) Data Storage Fast - experiment data is sampled and stored on-board the subsatellite at 16 bps for a maximum of 3072 seconds.

(d) Memory Readout - stored experiment data is read out of the on-board memory and combined with subsatellite subsystems data obtained in real-time and the resultant data stream is transmitted at 128 bps.

(e) Automatic Cycle - Upon initiation of this mode, the following sequence of operations will be done automatically and will repeat continuously:

    (1) switch on real-time mode for 448 seconds,

    (2) switch on memory readout mode for 512 seconds, and

    (3) switch on data storage normal mode for 6144 seconds.

(f) Stand by - no data will be transmitted or stored and the S-band transmitter will be turned off.

Whenever Doppler tracking data is being gathered, the subsatellite will be commanded to operate in the real-time mode. If it is assumed that the on-board battery is fully charged when the subsatellite is commanded into the real-time mode, the subsatellite can operate for up to 12 continuous hours in this mode using power generated by the solar cell array and power stored in the battery before the low voltage cut-off circuitry associated with the battery (which operates at 10 volts) will deactivate the transmitter and place the subsatellite in the standby mode. A chart showing the power balance for the P&F Subsatellite is included as Attachment 3.

The power supply subsystem of the subsatellite will include two independent DC-DC converters. One of these DC-DC converters will be used to provide the necessary voltages and power to operate the S-band transmitter, the S-band receiver, and the command decoder. The second DC-DC converter will be used to provide the necessary voltages and power to operate the data storage unit (DSU), the digital electronics unit (DEU), the high voltage power supply, and the particles and fields experiments.

Many of the meeting attendees including the writer were interested in the predicted dynamics of the subsatellite and the attitude stabilization of the subsatellite during the following four portions of the subsatellite mission: (a) subsatellite launch, (b) boom deployment, (c) decay of all motions other than pure spin (wobble decay), and (d) long term coast when gravity and solar torque are all the major orbit perturbations. Mr. R. Gluck of TRW has analyzed in some detail subsatellite attitude stabilization during boom deployment and during the long term coast, but has expended little effort to date in analyzing subsatellite attitude stabilization during subsatellite launch and wobble decay. It was noted that it is required that all subsatellite attitude motion other than pure spin be damped out to less than five degrees, that precession of the spin axis of the subsatellite be held to less than 35 degrees (20 degrees is the design goal) from the perpendicular to the ecliptic for 1 year and that the angular momentum vector and geometric longitudinal axis of the subsatellite be aligned to within five degrees. To date, all of the subsatellite attitude stabilization analyses for the boom deployment period has assumed that the subsatellite was a rigid body. This analysis was performed using a digital computer program which was developed for the Goddard Space Flight Center (GSFC) for use in the Pioneer Program. As a result of an analysis assuming undamped deployment of the three hinged 60 inch booms, it was decided that damping would be provided in order to avoid the weight penalty necessary for structural reinforcement.

In the analysis of the long term gravity and solar torque effects on subsatellite attitude stabilization, the solar torque effects were found to be negligible compared with the lunar gravity effects and were neglected in subsequent analyses. A digital computer program was developed for this analysis using for the lunar gravity model the fourth order closed form model developed by Jaffee of the Jet Propulsion Laboratory (JPL). In order to maintain the precession of the spin axis of the subsatellite within the required 35 degrees from the perpendicular to the ecliptic plane for 1 year for low (60 nautical mile) circular lunar orbits with inclinations ranging from 0 to 45 degrees, the ratio of the moment of inertia of the subsatellite about its longitudinal axis to the moment of inertia of the subsatellite about its transverse axis must be less than or equal to 1.1. Mr. Gluck calculated subsatellite attitude stabilization data on lunar gravity effects for 500 days. The results of this analysis indicate that precession of the subsatellite longitudinal axis with respect to the perpendicular to the ecliptic plane during one year could possible be held within 20 degrees if the subsatellite could be launched with its longitudinal axis in an orientation somewhat different from perpendicular to the ecliptic plane.

Although he has not done any detailed analyses, Mr. Gluck estimates that the wobble damper which will be provided in the subsatellite would cause a wobble of up to 15 degrees to decay to less than 0.5 degrees within about two hours.

3.0 ELECTRONICS SPLINTER GROUP MEETING

The Electronics splinter group meeting was co-chaired by Messrs. H. Vang, MSC/EE2, and F. Kelly of TRW. In general, all discussions on preliminary communications and power subsystems design was suppressed by the co-chairman until those sections of the technical portion of the End Item Specification for the P&F Subsatellite containing requirements bearing on the specific design of these subsystems had been read verbatim and any exceptions to these contents had been discussed. Action items, corresponding to Review Item Descrepancies (RID's) in a true PDR, were accepted by the co-chairmen only on these contents. A total of five action items were submitted by the participants of the Electronics splinter group meeting. These action items will be discussed in the following section (Section 4.0).

After the appropriate sections of the End Item Specification for the P&F Subsatellite had been reviewed, the cognizant TRW design engineers for the various elements of the communications and power subsystems were made available to answer questions on the preliminary design of these elements. The material on the preliminary design of the communications subsystem presented formally during the general briefing on the morning of May 14 and the discussions on this same subject during the splinter group meeting are summarized in this section. The communications subsystem of the P&F Subsatellite (see Attachment 2) includes the radio frequency communications equipment, the command decoder, the Digital Electronics Unit (DEU), and the Data Storage Unit (DSU).

3.1 RADIO FREQUENCY COMMUNICATIONS EQUIPMENT

The radio frequency communications equipment includes an S-band transponder, a DC-to-DC converter, a diplexer, and an S-band antenna as shown in Attachment 4 to this memorandum. This equipment will enable stations of the MSFN to track the subsatellite using two-way Doppler frequency measurements, to receive telemetry data from the subsatellite, and to transmit commands to the subsatellite. The S-band communications equipment will be compatible with stations of the MSFN in every respect including command and telemetry signal formats, modulation techniques, and frequencies except the frequency of the subcarrier generated on-board the subsatellite which will be modulated by the PCM telemetry data stream generated on-board the subsatellite. The operating carrier frequencies assigned to the subsatellite S-band transponder will be identical to those currently assigned to the Lunar Module (LM) of the Apollo Program; namely, receive-2101.8 MHz and transmit -2282.5 MHz. The S-band transponder can be operated in any one of the following three modes:

(a) the receiver is on and the transmitter is off,

(b) the transmitted carrier is coherently related to the received carrier by the ratio of $\frac{240}{221}$, and

(c) the receiver is on but not phase locked to the MSFN transmitted carrier and the transmitted carrier is not phase related to the MSFN transmitted carrier.

The receiver will be active continuously from the time of activation at separation of subsatellite from the CSM; however, the transmitter may be commanded on or off from the Earth. If the transmitter is on, the transmitted carrier will be phase locked to the received carrier automatically whenever the receiver is phase locked to the received carrier. Commands will be sent to the subsatellite from the Earth on a 70 kHz subcarrier which phase modulates the S-band carrier transmitted by a station of the MSFN. Telemetry data will be transmitted to a station of the MSFN on a 32.768 kHz subcarrier which phase modulates the S-band carrier transmitted by the subsatellite. This S-band transponder will be a slightly modified version of the S-band transponder (TETR-C) developed to be carried by the Test and Training Satellite for the Goddard Space Flight Center to be used for exercise of the stations of the MSFN. The slight modification to this transponder is required to make the transponder "magnetically clean." The output power of the transmitter of this transponder will be 0.5 watt minimum and 0.8 watt nominal.

The diplexer is provided so that the transmit and receive portions of the S-band transponder can share the single S-band antenna simultaneously. A Lindenblad antenna which is an antenna array will be mounted on the longitudinal axis of the subsatellite approximately 10 inches from the body of the subsatellite. The radiation pattern of this antenna should be similar to that of a dipole, a toroidal pattern providing a nominal gain of 3dB with circular polarization and with half-power points of the pattern located at $\pm$ 38 degrees from the plane perpendicular to the subsatellite longitudinal axis. TRW is currently measuring the radiation patterns provided by this type of antenna mounted at different locations from the main subsatellite body using a mockup of the subsatellite.

3.2 COMMAND DECODER

The command decoder is provided to demodulate the 70 kHz subcarrier detected by the S-band receiver and to decode the command message transmitted by a station of the MSFN. As is the case in the Apollo Program, the 70 kHz subcarrier will be frequency modulated by a composite signal consisting of a 1 kHz synchronization tone linearly summed with a 2 kHz tone biphase modulated at a 1 kHz rate by the digital command message. The digital command message format will be identical to the format used for real-time commands in the Apollo Program; the first 3 bits will be the vehicle address, the second 3 bits will be the system address and the final 6 bits will identify one of 32 possible control commands. Each of these 12 bits will be sub-bit encoded into 5 sub-bits. The command decoder of the subsatellite will be capable of accepting and implementing up to 32 control (on or off) commands. This command system will be similar to the command system of the CSM provided by Motorola, Inc., however, a phase-lock loop discriminator will be used instead of a conventional FM discriminator for reasons of weight and volume reduction. Studies are being conducted by TRW to assure that the phase-lock loop discriminator will not lock-up on a sideband of the received signal. Power will be removed from the command decoder during those periods of the subsatellite mission when the receiver of the S-band transponder is not phase-locked to a received carrier. As soon as phase-lock is achieved by the receiver, power will be provided to the command decoder. The command decoder will provide an indication to the DEU whenever a valid command message has been received which will be included once in each of four successive frames of the PCM data stream transmitted to the MSFN. However, due to the mechanization of the DEU and DSU discussed below, the first appearance of the MAP in the transmitted PCM data stream may be up to 27 seconds after the valid command message was successfully received and decoded by the command decoder.

3.3 DIGITAL ELECTRONICS UNIT

The DEU includes five orientation status counters (spin period counter, spin counter, sun phase counter, sun angle counter, and magnetic zero crossing phase counter), a magnetic sector generator, a spin period generator, a crystal controlled clock and elapsed timer, the pulse accumulators, the PCM telemetry equipment, and the telemetry data modulator. Outputs from the magnetic sector generator and the spin period generator are required by the particles experiments so that the particle counter accumulation period corresponds to an exact number of spin periods except for one particle detector whose counts output will be accumulated over different fractional parts of the subsatellite rotation by different counters as determined by the magnetic sectoring logic. Data from the five orientation counters will be required on Earth so that the data from the particles and fields experiments may be reduced and analyzed. Most of the elements to be used in the DEU will be identical to those which will be used in the Pioneers F and G.

The crystal-controlled clock will provide all timing signals required by the various subsystems of the subsatellite and will generate an elapsed time signal which will be stored during the normal and fast data storage modes of operation of the subsatellite and will be included in the real-time PCM telemetry stream generated during the real-time mode of operation of the subsatellite. The frequency of the crystal will be approximately 4.19228 MHz or more exactly 2^{22} Hz. The elapsed time word will have a resolution of one second and will recycle at the conclusion of each 18 hours. Since the crystal-controlled clock provides the timing for the PCM telemetry equipment, the relative time of events or samples in the real-time or stored PCM telemetry format can be resolved within 50 milliseconds. It is intended that the elapsed timer will operate continuously throughout the useful lifetime of the particles and fields experiments in order to maintain relative time correlation of events. If power were to be removed from the DEU, the elapsed timer would cease to operate.

The pulse accumulators are provided to collect count data from each of the particle detectors of the particles experiment. Each of these accumulators will have a count capacity of 19 bits minimum and will be floating point accumulators. At the end of an accumulation period, the contents of an accumulator will be compressed into an 8 bit word which will be routed to the PCM telemetry equipment for real-time transmission to the Earth or for on-board storage. The location of the floating point will be defined by four of these 8 bits. The resolution of the particle count provided by this compression will be equivalent to 5 bits. Twenty-four bit MOS registers designed by the NASA Ames Research Center will be used as the pulse accumulators in the subsatellite.

The PCM telemetry equipment will include a programmer, a digital multiplexer, an analog multiplexer, an analog-to-digital converter, a digital comparator, a fixed word generator, and a combiner. The analog and digital multiplexers will use MOSFET switches. Conditioned (0-5.k2VDC analog, events, digital words) experiment and housekeeping data will be gathered by the PCM telemetry equipment via the analog and digital multiplexers from the 14 floating point accumulators, the magnetometer, the spin counter, the sunphase counter, and the sun angle counter and from the communications and power subsystems. This data will be processed and time division multiplexed into three selectable serial PCM data streams where a "one" is represented by a change in level and a "zero" is represented by no change in level (NRZ-M). The NRZ-M data stream selected will be related to the mode of operation of the subsatellite. When the subsatellite is in the data storage normal mode, an 8 bits per second (bps) NRZ-M PCM signal will be routed to DSU. When the subsatellite is in the data storage fast mode, a 16 bps NRZ-M signal will be routed to the DSU. When the subsatellite is in the real-time mode, a 128 bps NRZ-M PCM signal will be routed to the telemetry data modulator for immediate transmission to the MSFN. All analog data will be digitally encoded into 8 bit words with the most significant bit appearing first, all event data will be grouped into 8 bit words, and all digital data originating as digital words will be 8 bit words. The 8 bps and 16 bps NRZ-M PCM data streams will contain data from the identical sources except that the data sources will be sampled twice as fast by the format of the 16 bps NRZ-M PCM signal. The 128 bps NRZ-M PCM data stream will in general include the data from the same sources as the 8 and 16 bps PCM signals as well as data from additional sources and overhead data such as frame synchronization words. Two eight channel subcommutators will be used in the formats for all three of these PCM data streams. There will be 24 channels in the frame format for the 8 and 16 bps PCM data streams and 32 channels in the frame format for the 128 bps PCM data stream. As indicated above, 2 channels in each of these formats will be fed by data from two 8 channel submultiplexers. In order to economize the required on-board storage capacity in the DSU, housekeeping data such as transponder phase lock loop stress, signal present in the receiver of the transponder, the MAP signal from the command decoder, etc. and overhead data such as frame synchronization words, subframe count, subsatellite identification, etc. will not be included in the 8 or 16 bps NRZ-M PCM signal formats. Since this overhead information is not included in the data stored in the DSU, an interlock will be included in the PCM telemetry equipment which will preclude a change in operational mode (e.g. from data storage normal to real-time) until the eight channel subcommutator has completed its full cycle and an integral number of frames have been completed. Consequently, in the worse case which will occur when changing from the data storage mode to another mode, 24 seconds may elapse before the mode of operation of the PCM telemetry equipment can be changed in response to a command from the MSFN. Also as a consequence of this effort to reduce the required storage capacity of the DSU, the contents of the DSU cannot be dumped directly to the MSFN via the telemetry subcarrier which phase modulates the S-band carrier transmitted by the S-band transponder when the subsatellite is commanded into the memory readout mode. The contents of the DSU instead will be readout to the PCM telemetry equipment as controlled by the PCM telemetry equipment which will add the overhead data and the real-time housekeeping data to the 24 word frame stored in the DSU to produce a 32 word frame format. The first four words of each frame of the memory dump data format will include the inserted overhead data and some real-time housekeeping data and words 17 through 21 of each 32 word frame of the memory dump data format will be composed of inserted real-time housekeeping data. When the subsatellite is in the memory readout mode, this reconstituted NRZ-M PCM bit stream will be routed to the telemetry data modulator at a rate of 128 bps. When the subsatellite has been commanded into the standby mode, no PCM data streams generated by the PCM telemetry equipment will be transmitted in real-time to the MSFN or stored on-board in the DSU nor will data be readout of the DSU for dump transmission to the MSFN.

The 128 bps real-time NRZ-M PCM data stream or the 128 bps memory readout NRZ-M PCM data stream routed to the telemetry data modulator will be used to phase shift key a 32.768 kHz square wave subcarrier in the telemetry data modulator.

The 32.768 kHz square wave subcarrier will be derived from the crystal-controlled clock discussed above. The modulated subcarrier will be routed to and will phase modulate (1.0 radian peak deviation) the transmitter of the S-band transponder whenever the transmitter is active.

3.4 DATA STORAGE UNIT

The DSU to be used on the subsatellite will be identical to the magnetic core memory units developed for use in Pioneers F and G. In this application in the subsatellite, not all of the input and output functions provided with this magnetic core memory unit will be utilized. The design of this memory unit has already undergone detailed design reviews for the Pioneer Program and has been breadboard tested. A detailed block diagram of the DSU is attached to this memorandum (Attachment 5). The total storage capacity of the DSU will be 49,152 bits. When the DSU storage capacity has been exceeded, the DSU will initiate a signal to the DEU which will place the subsatellite in the standby mode. If for any reason the data storage mode (fast or normal) of subsatellite operation was interrupted, the contents of the DSU must be dumped or be lost because when a data storage mode is again initiated, the data will be stored in the first address locations in the memory rather than in the memory address locations immediately following the address location where the last data was stored. Operation of the DSU will be controlled through the DEU. The contents of the DSU will not be destroyed during read out.

4.0 ACTION ITEM REVIEW AND DISPOSITION

The splinter groups were reunited for a meeting on the afternoon of May 15 when the action items submitted in each of the splinter group meetings on the requirements contained in the technical portion of the End Item Specification were read and discussed. On each action item form was included a statement of the problem, a statement justifying the validity of the problem, a recommendation of a suitable solution, and finally comments on the action item by TRW. After discussion on each action item, Mr. Johnson, NASA Experiment Manager, approved the recommendation, disapproved the recommendation, or assigned the action item to the appropriate agency (TRW, Principal Investigators, or NASA/MSC) for study. The action items submitted in each of the splinter group meetings are discussed in the following paragraphs.

4.1 ELECTRONICS SPLINTER GROUP

A total of 5 action items was submitted by the Electronics splinter group. Of this total, one action item concerning corona testing was withdrawn and two action items could be considered largely editorial in nature. The remaining two action items were submitted by the Principal Investigator for the S-Band Transponder Data Analysis Experiment. The recommendations for requirement changes contained in both action items which could affect the existing preliminary design of the subsatellite were made with the aim of increasing the data yield from the tracking experiment. The PI indicated that as much two-way Doppler data from the subsatellite in lunar orbit as could possibly be obtained was desirable especially during those periods just after line-of-sight between the subsatellite and a station of the MSFN is established as the subsatellite comes from behind the moon and just before line-of-sight is lost as the subsatellite goes behind the moon. In order to obtain the tracking data immediately before the subsatellite goes behind the moon without risking the possible failure to command the S-band transmitter off before line-of-sight is lost, the PI recommended that when the subsatellite is operating in the real-time mode, the subsatellite transmitter should be turned-off automatically and the subsatellite be put into the standby mode of operation after some arbitrary delay after the receiver of the subsatellite transponder has lost phase lock with the S-band carrier transmitted by an MSFN station. In the second action item the PI recommended that the capability be provided to deactivate simultaneously (and reactivate, if necessary) the particle and fields experiments and the DEU of the subsatellite so that power could be conserved after completion of the particles and fields experiments (at the end of one year or after a failure) so that more two-way Doppler data could be obtained per day. This could be accomplished by removing power from that DC to DC converter used to provide power to the DEU and the particles and fields experiments. Mr. Johnson directed TRW to incorporate these design change recommendations in the subsatellite design since TRW indicated that these changes would have only a minor cost impact.

4.2 SCIENTIFIC INSTRUMENTS SPLINTER GROUP

A total of 19 action items was submitted by the Scientic Instruments splinter group. Of this total, one action item was essentially a duplicate of another action item, 13 action items could be considered editorial including clarifications to existing requirements and addition of requirements for desirable capabilities already in the preliminary design of the subsatellite, and 5 action items recommended changes in requirements which would affect the existing preliminary design of the subsatellite.

The PI for the Magnetometer Experiment was concerned over the wide temperature variation (± 20 degrees Centigrade) of the magnetometer mounted at the end of one of the three 60 inch booms because of the sensitivity of the data output from the magnetometer to changes in temperature of the instrument. If the allowable temperature variation were permitted to remain ±20 degress Centigrade, the PI would require temperature measurements on the magnetometer to be telemetered to the MSFN with magnetometer data so that the data could be properly interpreted. If the temperature variation of the magnetometer could be held to within ±10 degrees Centigrade, the PI believes that a record of the temperature of the magnetometer would not be required. Mr. Johnson indicated that addition of a temperature sensor on the magnetometer was undesirable for two reasons: (a) the already crowded telemetry format and (b) the design problem of running additional wiring from the subsatellite body to the magnetometer. Mr. Johnson assigned TRW a task to investigate in detail the predicted temperature variation of the magnetometer and determine whether the tighter temperature variation desired by the PI could be maintained by using other methods of passive thermal control such as super-insulation. The results of this investigation should be available by mid-June.

The PI for the Magnetometer Experiment indicated that subsatellite inertial attitude information is essential for interpretation of the data from both the particles and the fields experiments. At the present time, a requirement does not appear in the End Item Specification for the P & F Subsatellite for inertial attitude determination and no attitude sensors are included in the preliminary design of the subsatellite which would provide this information directly. TRW believes that the inertial attitude of the subsatellite could be determined over a time interval,perhaps three months,but not on a daily basis from data on sun elevation angle, sun azimuth angle, and time of crossing of the zero magnetic flux line which will be telemetered to the MSFN. Mr. Johnson assigned a task to TRW to investigate how the inertial attitude of the subsatellite could be determined and with what accuracy without requiring additional instrumentation on-board the subsatellite.

A representative from the Flight Control Division (FCD) - Experiment Systems, Mr. Brizzolara, recommended that the resolution of the elapsed timer be reduced from 1 second to 16 seconds which would increase the timer recycle period from 18 hours to 12 days. Since the elapsed timer and the PCM telemetry equipment both derive their timing signals from the on-board crystal controlled clock, the relative time correlation of events or data samples can be maintained at 50 milliseconds with the recommended change implemented. Since TRW indicated that implementation of this recommendation would result in no cost or schedule impact, Mr. Johnson directed TRW to implement this change.

Mr. Brizzolara recommended that separate commands be implemented which will enable the particle detectors to be turned on or off or the magnetometer to be turned on or off independently by the MSFN in order to protect the remaining subsystems of the subsatellite in case of failure of one of the experiments. It was pointed out that the high voltage supply providing power to the channeltrons of the particle detectors can be turned on or off by command from the MSFN. Possible failures in the channeltrons appear to be the only failure modes in the experiments which could compromise the operation of the remaining subsystems of the subsatellite. Mr. Johnson rejected this recommendation for the time being until the failure mode and effects analyses can be completed on the Magnetometer Experiment and on the Lunar Particle Shadows and Boundary Layer Experiment.

Mr. J. Garder, TRW chairman of the Scientific Instruments splinter group meeting, recommended that the command list appearing in the End Item Specification be modified to reflect the current preliminary design of the subsatellite. Mr. Johnson requested that TRW provide written justification for each change in this command list and deferred a decision on this action item until MSC had studied the recommendation and justification for each command change.

4.3 MECHANICAL SPLINTER GROUP

A total of 6 action items was submitted by the Mechanical splinter group. Of this total, 3 action items could be considered clarification of existing requirements or addition of requirements to the End Item Specification reflecting the current preliminary design of the subsatellite, 2 action items were concerned with extending the period of time that the subsatellite will remain with its longitudinal axis within 35 degrees from the perpendicular to the ecliptic plane, and one action could affect the current design of the subsatellite.

TRW will investigate the effect on the lifetime of the subsatellite as defined above if (a) the subsatellite were not designed for lunar obit inclinations of up to 45 degrees but only for inclinations consistent with the expected inclination of the CSM orbits during the missions of interest in the Apollo Program and (b) the subsatellite were launched from the CSM with the nominal attitude of the longitudinal axis of the subsatellite different from the perpendicular to the ecliptic plane.

The PI for the Magnetometer Experiment indicated that misalignment of the magnetometer by as much as 5 degrees from the principal axis of inertia of the subsatellite will result in excessive error in interpretting the data from the magnetometer, but that a 1 degree misalignment was acceptable. Current requirements in the End Item Specification of the P & F Subsatellite allow a misalignment between the angular momentum vector and the geometric longitudinal axis of the subsatellite of up to 5 degrees. Since it is planned that the magnetometer will be aligned with respect to the geometric longitudinal axis of the subsatellite, the 5 degree alignment requirement is unacceptable to the PI. It was pointed out that the misalignment between the angular momentum vector and the geometric longitudinal axis of the subsatellite could be measured within 1 degree after the subsatellite has been fabricated. After this misalignment was measured, the magnetometer could be aligned to the measured direction of the angular momentum vector. Mr. Johnson directed TRW to use this procedure in aligning the magnetometer rather than reducing the 5 degree misalignment requirement to 1 degree in the End Item Specification which would be a major impact item.

4.4 PROGRAM PLANS SPLINTER GROUP

No action items were submitted by the Program Plans splinter group. However, Mr. Johnson revised the schedule for the TRW delivery of the Failure Mode Effects Analysis (FMEA) for the subsatellite to two weeks before the date for the CDR.

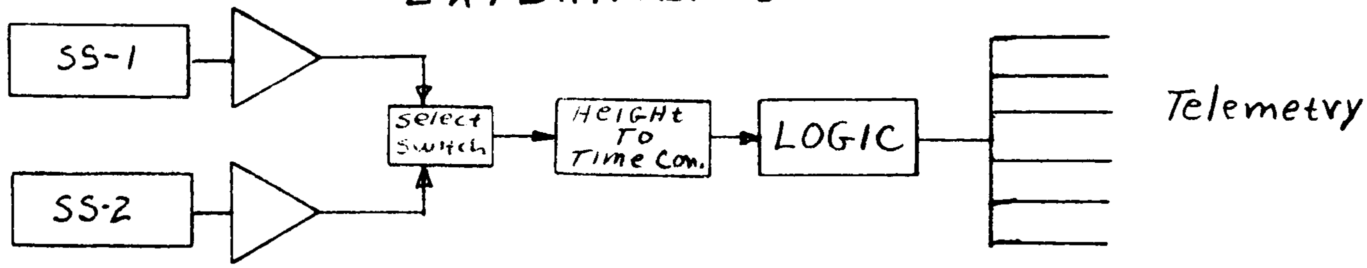
A. G. Weygand

A. G. Weygand

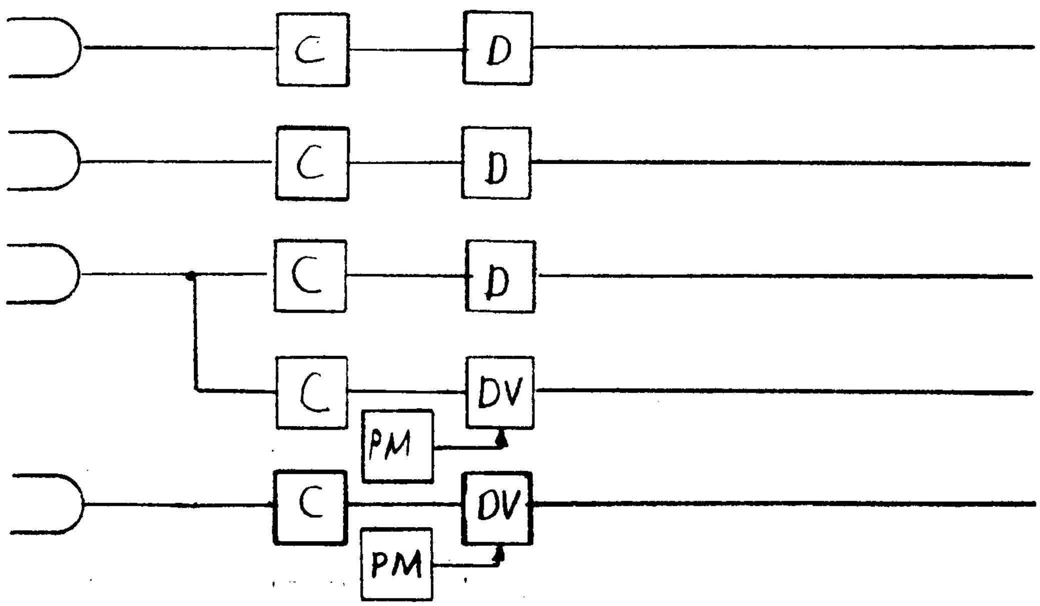
2034-AGW-pjr

Attachments I-V

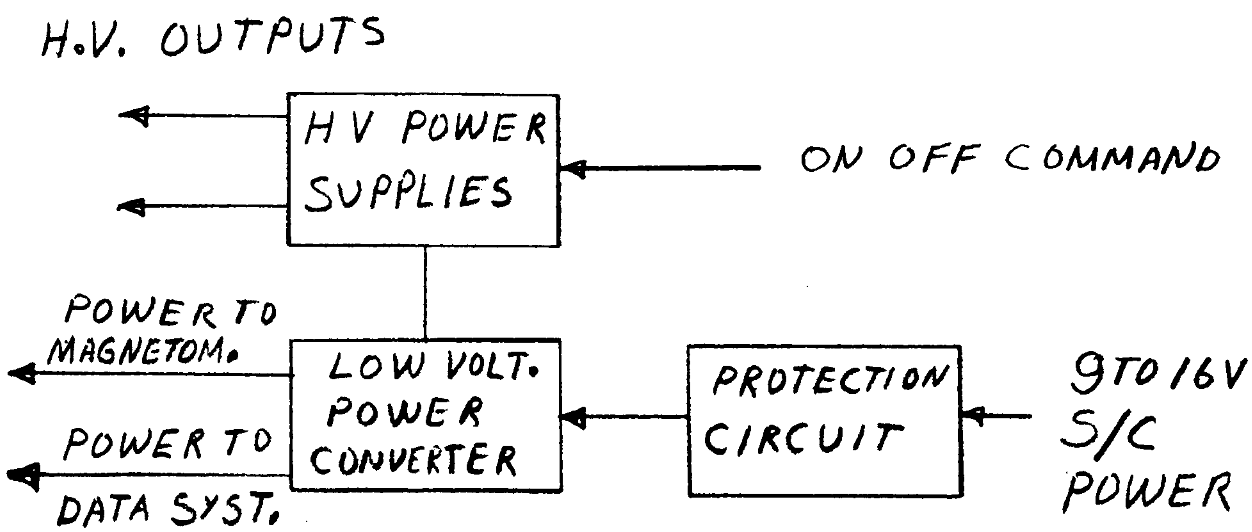
EXPERIMENTS



SOLID STATE TELESCOPES



CURVED PLATE ANALYZERS



POWER SUPPLIES

GMC 5/12/70

EXPERIMENTS

Particles

Description

Solid State Telescopes

2 Telescopes selected alternately by telem.
Specific detector not yet slected
One telescope is shielded $50\mu g/cm^2$
Each telescope consists of two stacked solid state detectors with corresponding charge sensitive amplifiers and proper veto logic.
This is followed by a height to time converter and logic to produce 6 outputs synchronous with clock.
Telescope 1 - Protons .3-6 Mev; Electrons 20-320 Kev
Telescope 2 (Shielded) - Protons .6-6 Mev; Electrons 30-320 Kev
Mounted || to spin axis.

Curved Plate Analyzers

4 analyzer assemblies - respond only to electrons. Use continuous channel multipliers
5 outputs with two channels guarded by plastic scintillators and PM tube
Energy ranges - .5 to 16.5 KEV

EXPERIMENTS

Particles (Contd)

Experiment viewing ⊥ S/c spin axis
Particles Experiment Power 1.123 Watts

<u>Power Supplies</u>

High Voltage

<u>Positive</u> 5 KV supply tapped for analyzer plates and channeltron bias.

<u>Negative</u> 3.5 KV supply for PM tube

80 volts for solid state detectors.

High Voltage on - off command

<u>Particles Experiments Status</u>

<u>Contractor</u> Selected - Analog Technology Corporation, Pasadena, California

Selected for technical excellence and off-the-shelf design.

Design Status

80% of the electronics can be packaged; 50% as is; 30% with minor modifications.

Designs

Solid State detectors	OSO-H
Curved Plate analyzer Elect. *	ATS-E
H.V. Power Supplies *	ATS-E

EXPERIMENTS P. 3

Logic Similiar to U of I Exp Pioneer F&G

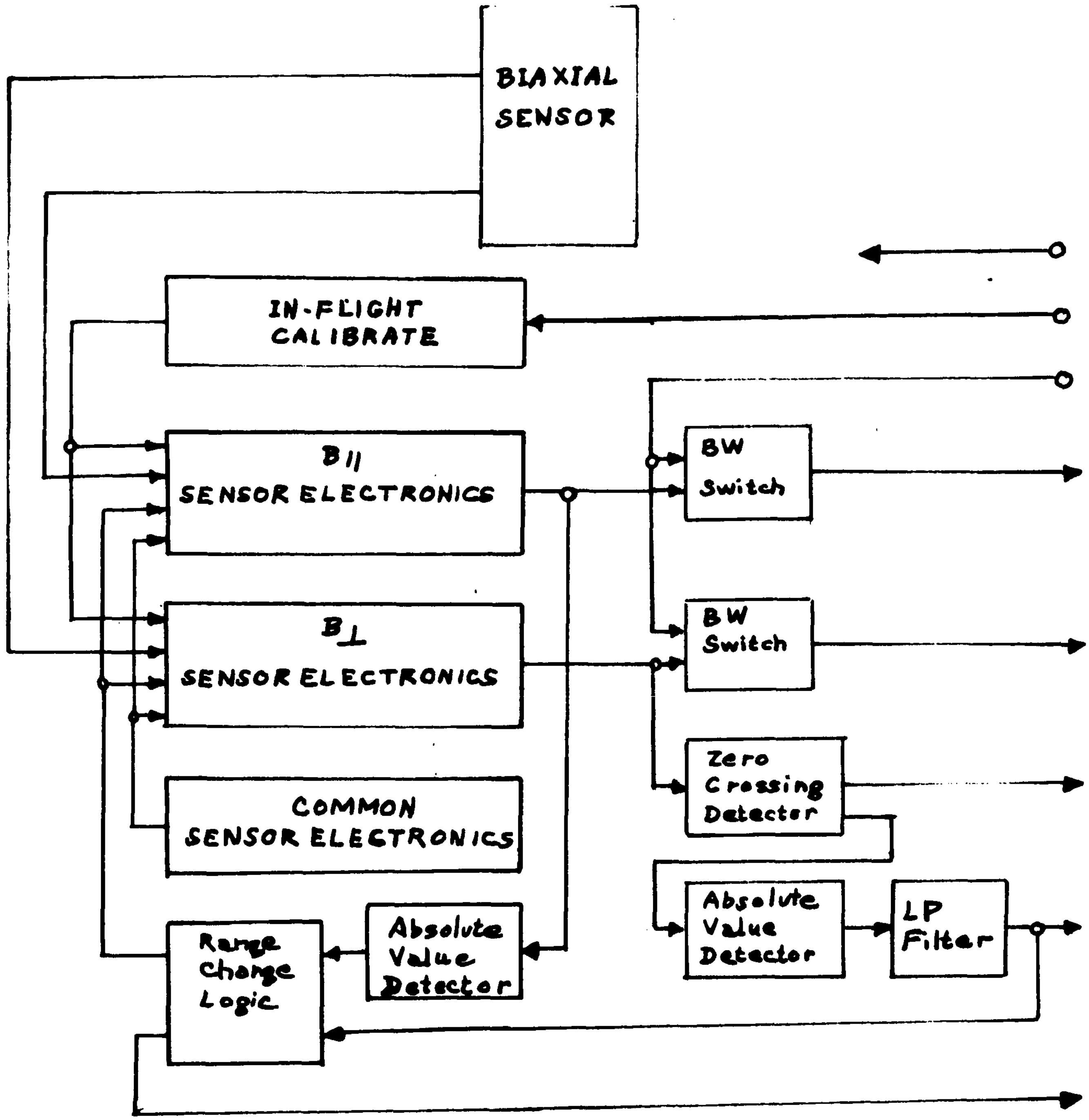
Other Power Supplies IMP H&J

Apollo γ Ray Spectrom.

Program Startup

By GO-Ahead + 2 weeks. The following accomplishments are expected

1. Detailed Schedules
2. Preliminary (80%) parts Lists
3. Preliminary Detailed Block Diagrams
4. Select and Order SS Detectors
5. Identify and Order all long leadtime parts.
6. Copies of episting module schematics
7. Semi final definition of S/C-Expperiments electrical interface.
8. Preliminary S/C Expperiment mechanical interface.



MAGNETOMETER

EXPERIMENTS

FIELDS

<u>Description</u>

- 2 axis Fluxgate Magnetometer
- Sensors on a boom
- 2 ranges 0-50 γ and 0-200 γ automatically switched with 10 γ hysteresis.
- Zero crossing detector puts out a pulse when the magnetic field of B ⊥ crosses zero going positive
- Bandwidth - switched 1 Hz Store

  5 Hz direct by command
- Output Analog 5 Volts, zero centered at 2.5 Volts
- Power Required .56 Watts

Field Experiment Status

Contractor Selected - Time Zero, Inc.
Torrance, California

Selected for technical excellence and great experience in the design and manufacture of space magnetometers

Design Status
Circuit Design 75%
Package and Module design to be determined applicable

Previous Designs

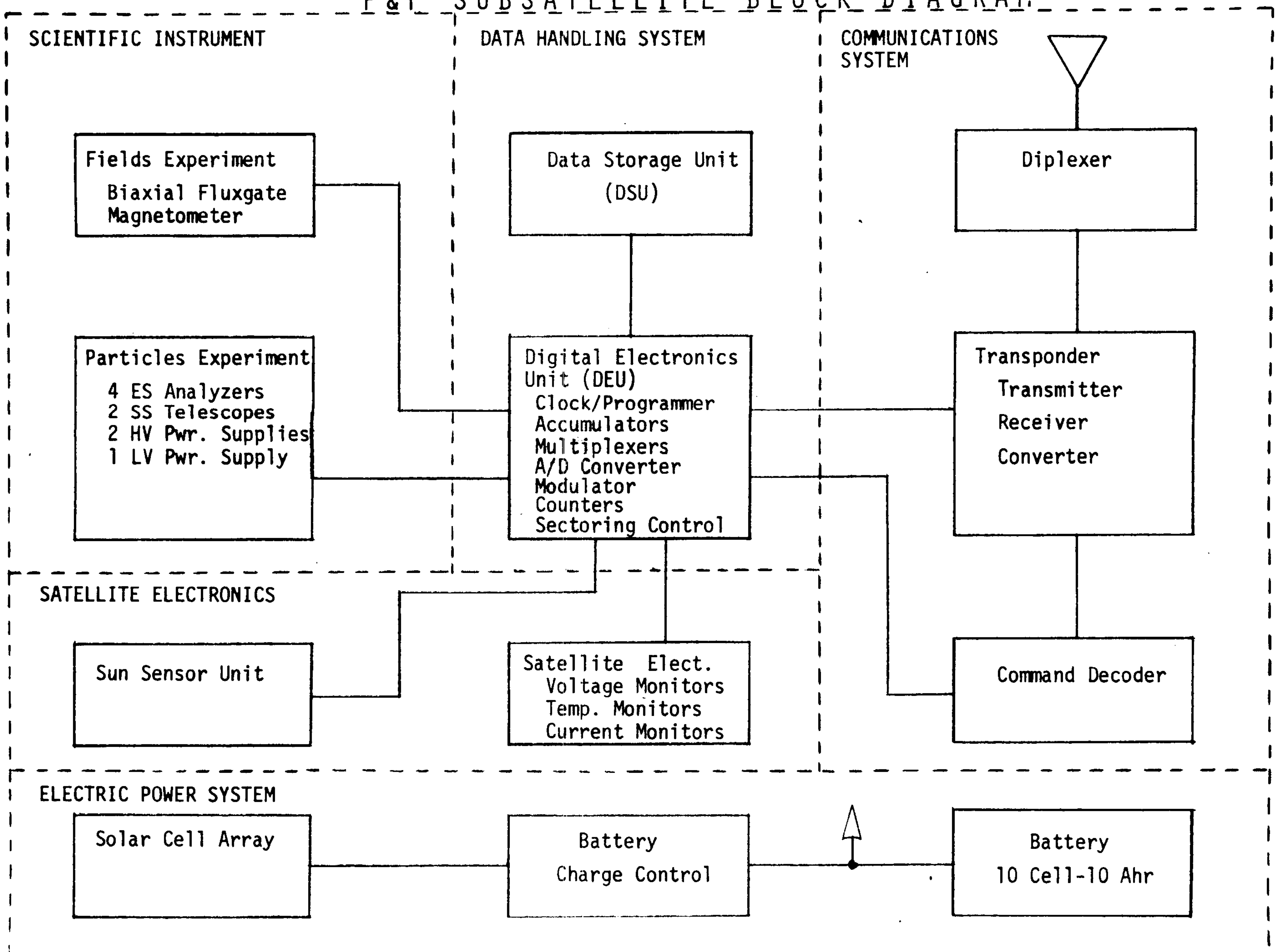
Magnetometers for
OGOs I, II, III, IV, V
Mariner II
Gemini
Javelin
Surveyor
Mariner A

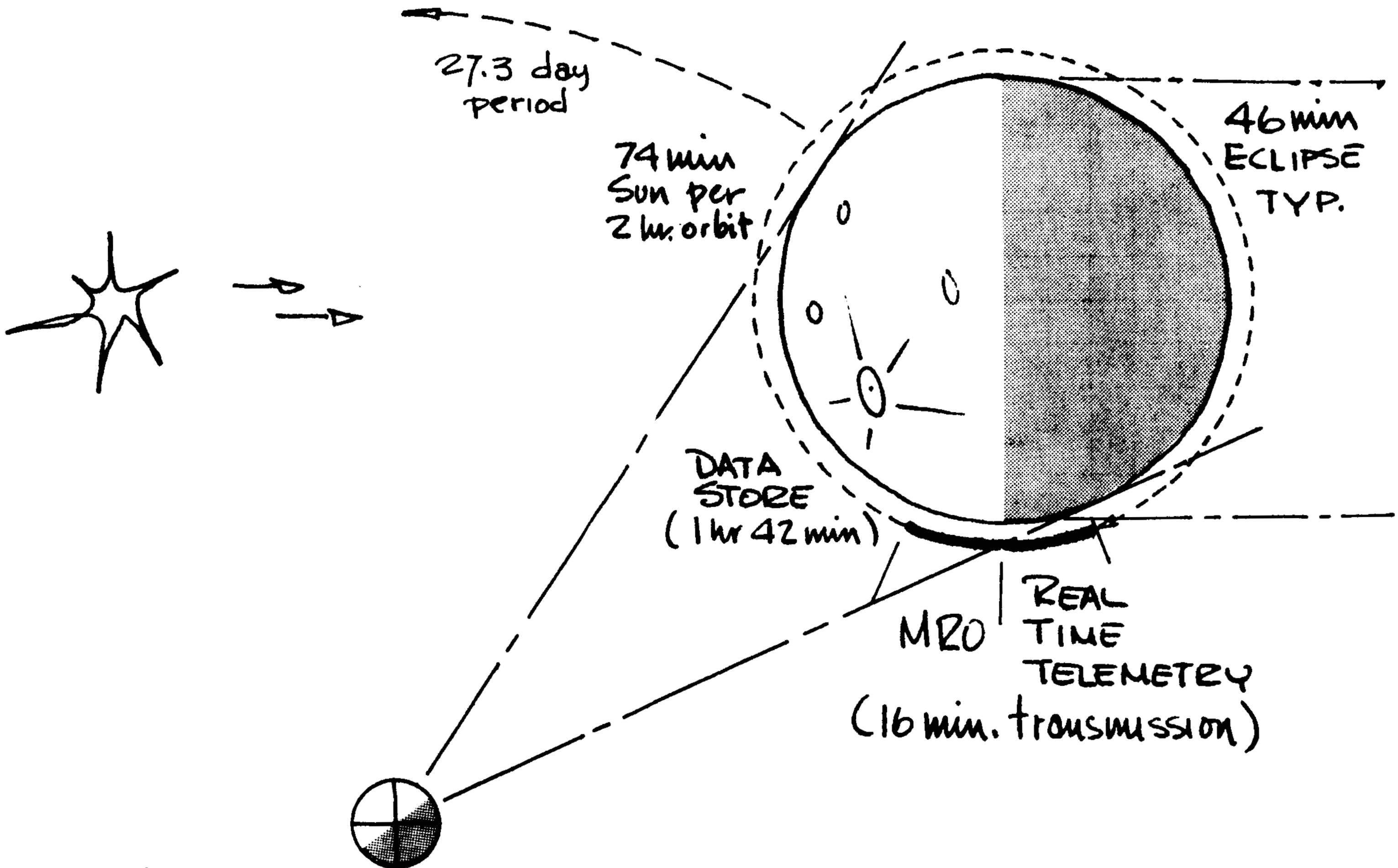
Program Startup

By Go ahead + 2 weeks the following accomplishments are expected

1. Detailed Schedules
2. Preliminary (80%) parts lists
3. Preliminary block diagrams
4. Order flux gate sensor
5. Identify and order other long leadtime parts.
6. Copies of existing module schematics
7. Semi-final definitions of S/C Experiment electrical interface.
8. Preliminary S/C Experiment mechanical interfaces.

P&F SUBSATELLITE BLOCK DIAGRAM



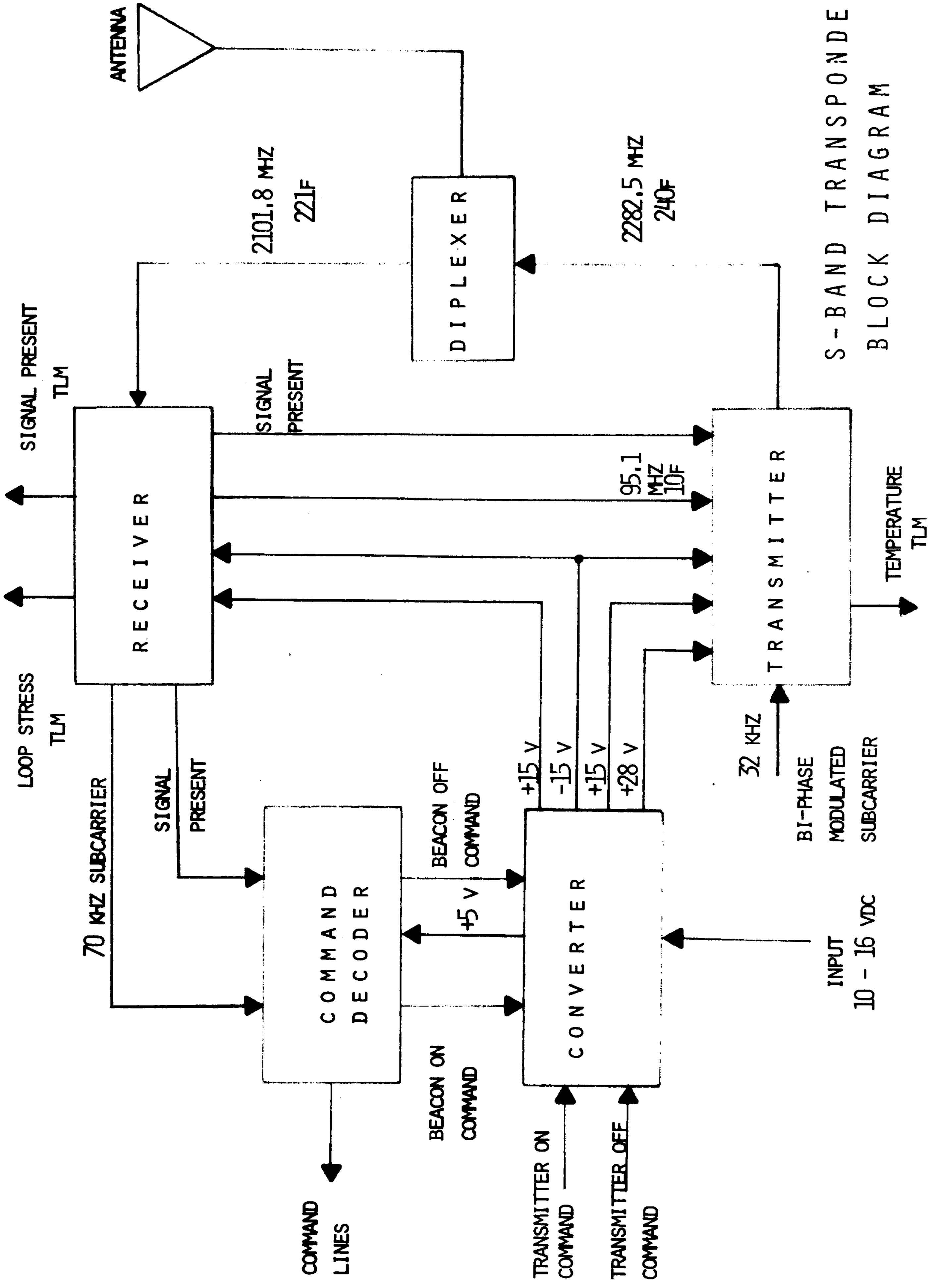


- Automatic: 16 min transmission per 2 hr. 21.7 W reqd.
  Causes 4.5% depth of discharge max, 61% zero.
  Orbit average power reqd 11.3 W (11.9 available)
- Tracking: 74 min transmission once per day. 22.8 W reqd.
  Causes 14.6% depth of discharge max, 14.1% avg.
- Data Store: Fill takes 1.7 hr. 9.7 W reqd.

- Battery charges at 15.4 V. Series elements 1.5 V → 16.9 V Solar bus.
  Average current at 16.9 V = 1.55 A → 23.9 W at 15.4 V.
  If spin axis misaligned 35°, 1.27 A → 19.5 W at 15.4 V
  39% of orbit is in eclipse → 11.9 W at 15.4 V

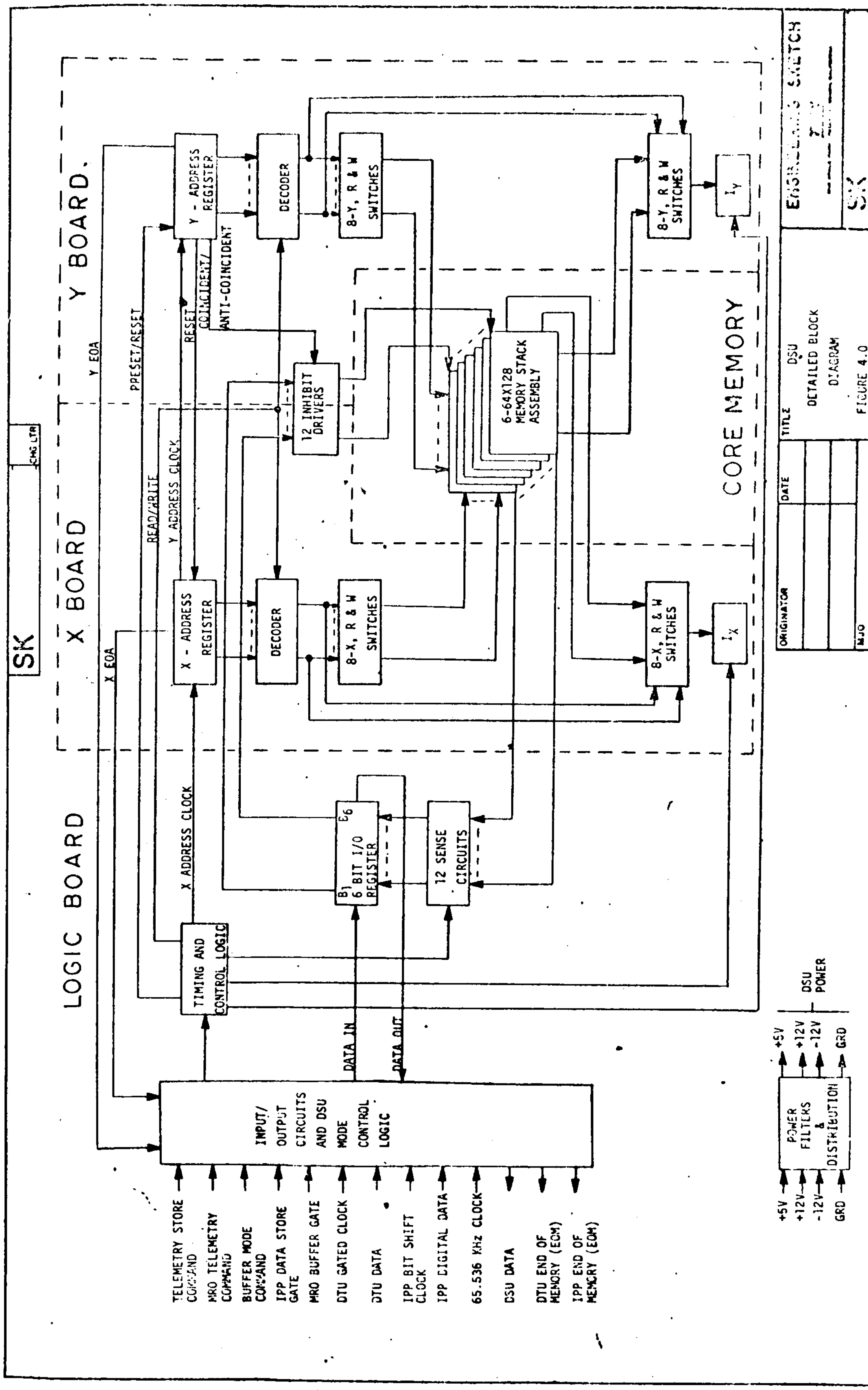
P&F POWER BALANCE

Attachment IV



S-BAND TRANSPONDER
BLOCK DIAGRAM

Attachment V



BELLCOMM, INC.

Subject: Description and Status of the Design of the Particles and Fields Subsatellite - Case 320

From: A. G. Weygand

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